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A PRELIMINARY ANALYSIS OF THE 1984 SIZE STRUCTURE OF HAWAII'S COMMERCIAL OPAKAPAKA LANDINGS AND A CONSIDERATION OF AGE AT ENTRY AND YIELD PER RECRUIT

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A PRELIMINARY ANALYSIS OF THE 1984 SIZE STRUCTURE OF HAWAII'S COMMERCIAL OPAKAPAKA LANDINGS AND A CONSIDERATION OF AGE AT ENTRY AND YIELD PER RECRUIT

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INTRODUCTION

Accompanying the expansion of the Hawaiian tourist industry through the 1970's and into the 1980's, there came a demand for high quality seafood products to satisfy the appetites of visitors. Deepwater snappers (Lutjanidae) and jacks (Carangidae) became popular with consumers through promotional efforts, a development which provided a substantial and stable market for the local handline fishery which harvests these demersal fishes. The single species which most epitomizes the growth which occurred within the fishery is the opakapaka, Pristipomoides filamentosus, which alone increased 340% in landings, from 24 to 106 metric tons (MT), from 1970 to 1980 (Hawaii Division of Aquatic Resources annual catch statistics). Today, opakapaka is known and accepted as a first class seafood product, which is marketed primarily within the State as fresh fillets to premium seafood restaurants.

Predictably, the rapid increase in demand for opakapaka and other deep-sea bottom fishes, coupled with the subsequent rise in landings, raised concern over the stability and productivity of the resource base. Ralston[1] first described the fishery in a report presented to the Western Pacific Regional Fishery Management Council (WPRFMC). Based on a subsequent programmatic assessment,[2] the Bottom Fish Planning Team of the WPRFMC began preparing a fishery management plan (FMP) for opakapaka and other species in the fishery. Research results available at that time (Ralston 1981, 1984; Ralston and Polovina 1982) suggested that the handline fishery around Maui, Lanai, Molokai (including the Penguin Bank), and Kahoolawe was: 1) harvesting at or slightly beyond a level of fishing effort expected to produce the maximum sustainable yield (MSY) and, 2) that a near maximum yield/recruit (Y/R) of opakapaka was being obtained under eumetric fishing conditions (i.e., an optimal age at entry for a given fishing mortality). Furthermore, landings from this particular bank, which is composed of but one single continuous extent of bottom fish habitat, historically accounted for over half of all State landings. Based upon these determinations it was concluded in 1981 that "...there is no pressing need to regulate the Hawaiian deepsea handline fishery. Exploitation at Penguin Bank, the most important fishing ground for these species in the State, appears optimal in the absence of any controls whatsoever" (Ralston 1981).

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[1] Ralston, S. 1979. A description of the bottom fish fisheries of Hawaii, American Samoa, Guam, and the Northern Marianas. A report submitted to the Western Pacific Regional Fishery Management Council, Honolulu, Hawaii, 102 p.

[2] Western Pacific Regional Fishery Management Council. 1983. Assessment of the bottom fisheries of the western Pacific region. Report submitted to the Western Pacific Regional Fishery Management Council, Honolulu, Hawaii, 246 p.

More recent evidence has become available, however, that suggests the fishery for opakapaka in the main high Hawaiian Islands is rapidly deteriorating. This conclusion is based on casual observations by people familiar with the fishery, as well as a sampling program implemented in 1984 by the WPRFMC at the Honolulu fish auction. What follows is a preliminary analysis of these data, demonstrating that significant changes have occurred in the high island fishery for opakapaka during 1980-84.

SOURCES OF DATA

Beginning in January 1984, WPRFMC staff began attending the Honolulu fish auction at the United Fishing Agency (UFA) daily to collect information concerning bottom fish transactions. At UFA a vessel's catch of bottom fish is auctioned off as individual pieces or by species and size specific lots. Before the sale the catch is counted, weighed and loaded either into metal tubs or onto wooden pallets. Each lot is tagged with a label giving the total weight of the lot and the number of pieces it contains. Lots are then placed on the auction floor for sale. Therefore, data were recorded by specific lots of opakapaka and included the total weight, number of pieces, price per pound, collection date, and an approximate location of capture (main Hawaiian Islands = MHI or Northwestern Hawaiian Islands = NWHI, see Fig. 1). The data were later summarized and tabulated to provide the average weight (lb), number of individuals, fishing location, and price per pound for all lots of opakapaka sold at the auction between mid-January and the end of February, 1984. Additionally, the total pounds of opakapaka and the total pounds of bottom fish marketed each day were tallied.

RESULTS

If opakapaka were sorted perfectly by size, there would be no variation in weight among individuals in a lot. The mean weight of fish in a tub would be equal to the specific weights of all the individual fish within it. In fact there is size variation within lots, although it is small relative to overall levels of variation. For example, analysis of variance of 694 individually measured uku, Aprion virescens, taken from a sample of 167 UFA lots, reveals that 91% of all weight variation was attributable to differences among lots (WPRFMC, unpublished data). Because variation in the size of individuals within lots is small (s.d. = 0.84 kg for uku), and concomitantly, variation in weight among lots is relatively large, as a first approximation it is reasonable to regard all of the fish within a lot to be of equal size. Although this is clearly a simplifying assumption, the amount of error introduced into the following calculations by this procedure is unlikely to affect the general conclusions of this study.

Under the assumption that the mean weight of individuals within a lot is equal to the actual weight of all the fish comprising it, weight-frequency distributions of opakapaka caught in the main islands (MHI) and the leeward islands (NWHI) of the Hawaiian Archipelago were developed. Figure 2 presents the resulting distributions as relative frequency and cumulative relative frequency polygons. It is clear from the upper portion of the figure that a much greater percentage of small fish are currently

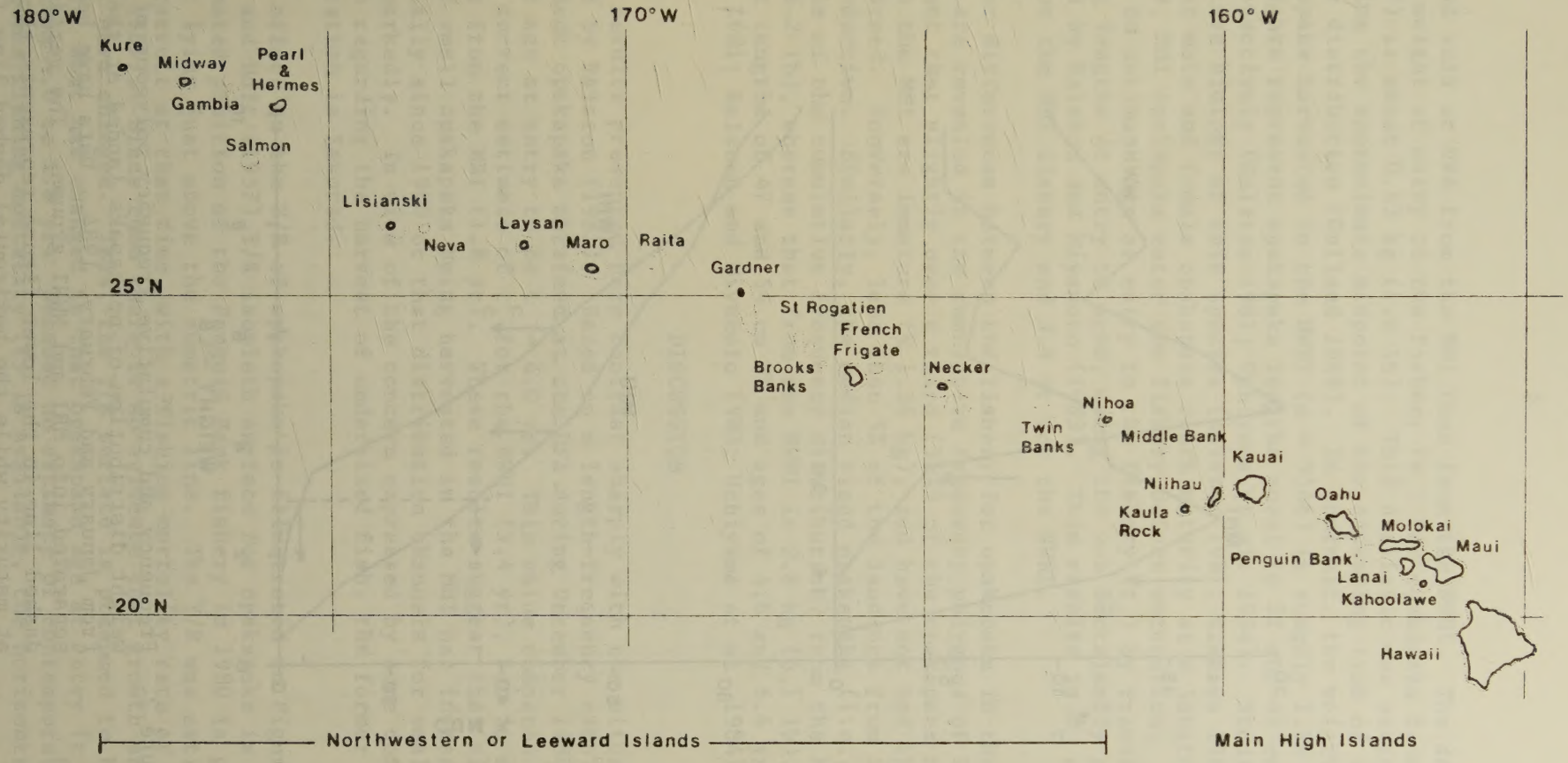

Figure 1. Map of the Hawaiian Archipelago showing the Main High Islands and the Northwestern Hawaiian or Leeward Islands.

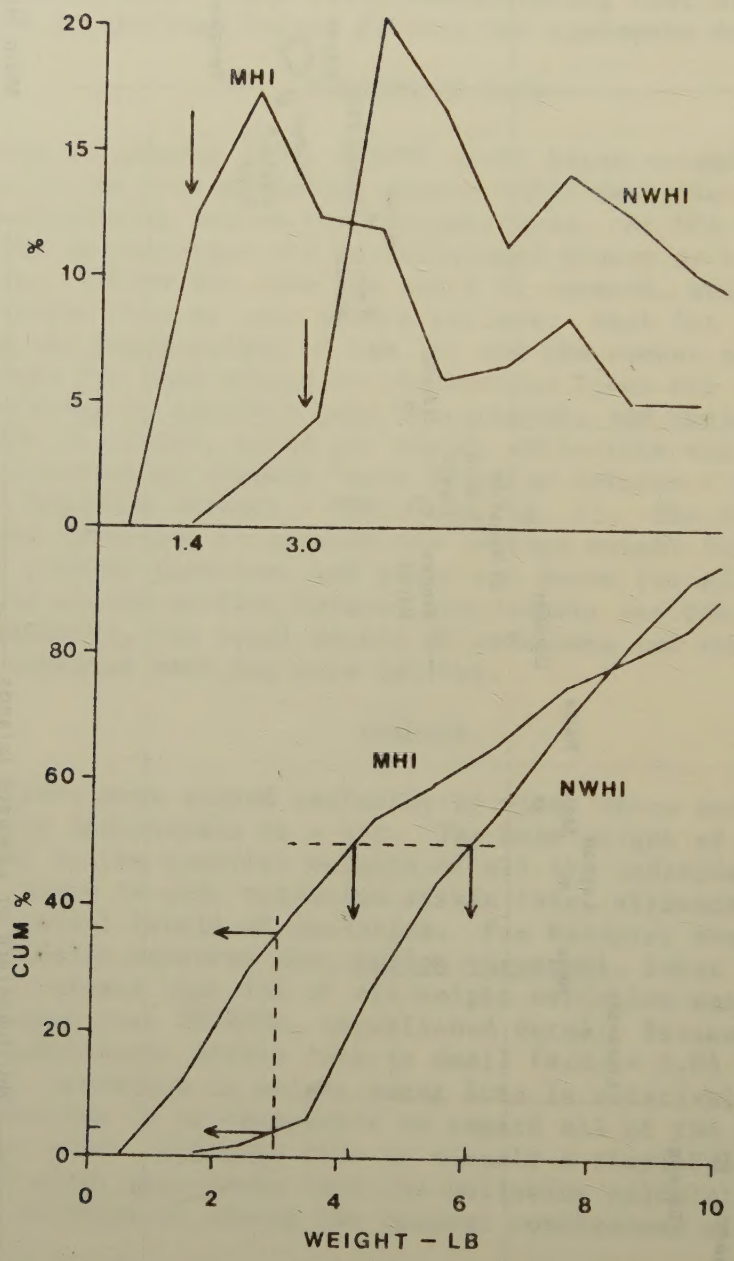

Figure 2. Frequency and cumulative frequency polygons of the weight distribution of opakapaka landed at the UFA from January and February, 1984. Data have been separated into MHI and NWHI groups. The vertical dashed line in the lower figure represents the size at maturity while the horizontal dashed line is placed at the 50th percentile.

landed and sold at UFA from the MHI than from the NWHI. The data also show that the weight at entry to the fishery (w_c) for opakapaka from the MHI (n = 1347) is about 0.63 kg (1.4 lb). This statistic was estimated by determining the approximate midpoint of the ascending limb of the size-frequency distribution (Gulland 1969). In contrast, the weight at entry for opakapaka harvested in the NWHI (n = 3546) is roughly 1.36 kg (3.0 lb). These weights represent opakapaka lengths equal to 31 and 41 cm fork length (FL), respectively (Ralston 1981; Uchiyama et al. 1984). Studies on the reproductive biology of this species (Ralston 1981; Kikkawa 1984) have shown that male and female opakapaka reach maturity at a length of 40 cm FL. Thus, MHI opakapaka enter the fishery before maturation. It is also possible to estimate age at entry to the fishery (t_c) by transforming the preceding lengths at entry to ages, using the von Bertalanffy growth curve developed by Ralston and Miyamoto (1983). This results in t_c estimates of 1.8 yr for the MHI fishery and 3.4 yr for the NWHI.

Other differences between the fishery for opakapaka in the MHI and in the NWHI are revealed in the cumulative frequency polygons of Figure 2. It is apparent that slightly over a third (36%) of the opakapaka now being landed in the MHI are immature (< 1.36 kg), and have not had the opportunity to breed. Conversely, less than 5% of the landings from the NWHI are pre-reproductive. Similarly, the median sized opakapaka (i.e., the 50th percentile of the cumulative frequency distribution) from the MHI is about 1.9 kg (4.2 lb), whereas that from the NWHI is 2.8 kg (6.1 lb). These represent lengths of 47 and 54 cm FL and ages of 4.6 and 6.4 yr, repectively (Ralston 1981; Ralston and Miyamoto 1983; Uchiyama et al. 1984).

DISCUSSION

The results presented here contrast sharply with the situation described by Ralston (1981). Based on a length-frequency sample of 175 Penguin Bank opakapaka obtained at the UFA during December 1980, he estimated age at entry to be t_c = 4.0 yr. This value compares favorably with the current estimate of t_c for the NWHI (3.4 yr), but is much greater than that from the MHI (1.8 yr). These results suggest that either the number of small opakapaka being harvested in the MHI has increased substantially since 1980 or that distribution channels for small fish have altered markedly. In view of the concern expressed by some commercial fishermen regarding the harvest of undersized fish, the former interpretation is favored.

The effect on the Y/R of opakapaka is illustrated in Figure 3, where a Beverton and Holt (1957) Y/R isopleth surface for opakapaka is presented. The estimated position of the Penguin Bank fishery in 1980 is given by the large dot lying just above the eumetric line. The Y/R was estimated to be 0.36 kg/recruit at that time, with a fishing mortality rate of 0.49 yr^{-1} (Ralston 1981). Since then there is no evidence that growth and natural mortality have changed. Thus, the Y/R surface is presumed to have remained unchanged. What has changed is that opakapaka age at entry (t_c) has dropped from 4.0 to 1.8 yr. Because no estimate of contemporary instantaneous fishing mortality (F) is available, the horizontal line at

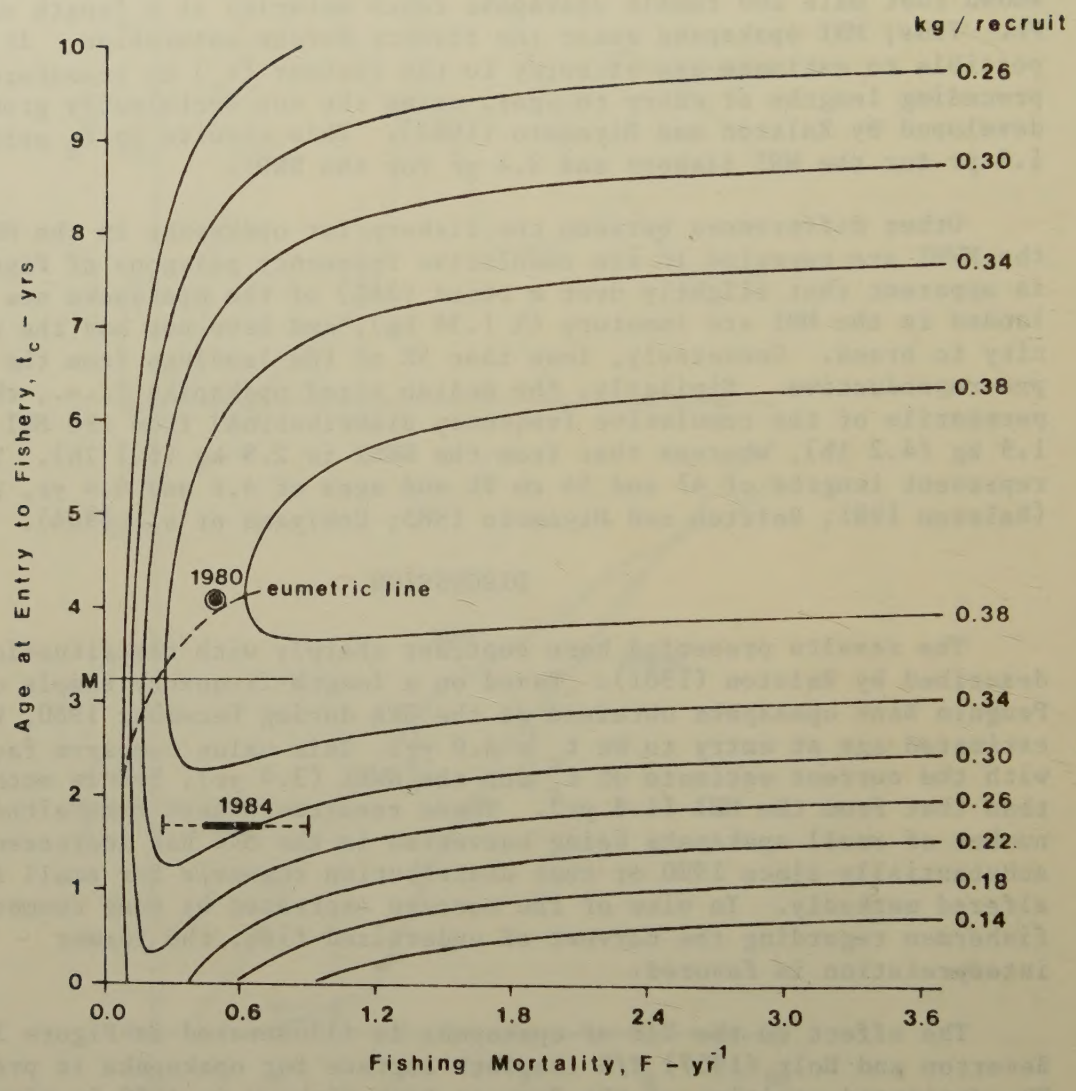

Figure 3. Yield per recruit (Y/R) isopleth diagram for opakapaka. The horizontal line labeled "M" represents the age at maturity for this species. See text for further discussion.

t_c = 1.8 yr is intended to represent a plausible range for the F value now in effect, and to indicate the estimated position of the fishery as of March 1984. Assuming no change in F from 1980 to 1984 it can be seen that Y/R has still dropped from 0.36 to roughly 0.30 kg/recruit, a 17% reduction.

To illustrate the effect of declining age at entry on opakapaka Y/R a number of calculations were performed. The steady state solution to the Beverton and Holt (1957) Y/R equation was evaluated assuming von Bertalanffy growth parameter estimates as given in Ralston and Miyamoto (1983) and a natural mortality rate of 0.25 yr^{-1} (Ralston 1981). The age at recruitment was assumed equal to birth, and growth was assumed isometric. The latter simplification has a relatively minor effect upon the computation of opakapaka Y/R and has the advantage of greatly easing solution of the yield equation (Ralston 1981). The model was evaluated under a variety of age at entry and fishing mortality conditions. The resulting values of Y/R (kg per recruit) are presented in the following table.

	Instantaneous fishing mortality (yr^{-1})			
Age at entry	0.45	0.50	0.55	0.60
1.4 yr (0.45 kg)	0.278	0.275	0.271	0.268
1.5 yr	0.283	0.280	0.277	0.273
2.0 yr (0.68 kg)	0.304	0.303	0.302	0.300
2.5 yr	0.320	0.321	0.321	0.321
3.0 yr	0.330	0.333	0.334	0.335
3.5 yr (1.36 kg)	0.335	0.339	0.342	0.344
4.0 yr	0.335	0.340	0.344	0.347

Across a realistic range of fishing mortality rates (0.45-0.60 yr^{-1}), increases in age at entry (t_c) result in increased Y/R. Currently, the State of Hawaii prohibits sale of opakapaka weighing less than one pound (0.45 kg), an old law enacted in the 1920's, presumably with economic considerations underlying its intent. Harvesting fish this minimum size corresponds to an estimated t_c = 1.4 yr and represents the legal lower bound for weight at entry to the fishery. The fishery in the MHI is currently thought to begin its harvest when individuals reach a weight of almost 0.68 kg (t_c = 2.0 yr). Based on the evidence presented earlier the fishery in the NWHI is believed to begin taking fish at a weight of 1.36 kg (t_c = 3.5 yr). Increasing age at entry from the current legislated state limit of 1.4 yr to that currently prevailing in the NWHI (3.5 yr), results in an average increase in Y/R of 25%. Similarly, increasing age at entry from the prevailing situation in the MHI (2.0 yr) to that of the NWHI leads to an average 13% increase in Y/R.

Although based on equilibrium assumptions which neglect transition costs,[3] it is clear from these data that substantial losses in Y/R have

[3]Waters, J. 1984. Dynamic yield per recruit analysis for establishing minimum size limits in the South Atlantic snapper-grouper fishery. Unpublished manuscript, Southeast Fisheries Center, SAW/84/RFR/1.

occurred due to harvesting undersized fish. Even greater wastage is possible under current law, a situation likely to become aggravated given the existing trend in the fishery. It is tempting to extrapolate these findings and conclude that similar losses have occurred to overall yield. In fact, there is every reason to believe that even greater gains in total opakapaka yield could be realized than those described previously, if opakapaka age at entry were increased. This is due to the lost potential reproductive contribution of individuals which are now harvested in the immature state. Increased reproductive output by these individuals could result in increased recruitment, leading to increased yield.

To assess the magnitude of this effect, the reproductive outputs of two cohorts of fish were calculated under differing steady state mortality regimes. The age and growth curve of Ralston and Miyamoto (1983) was used to define individual growth dynamics. Kikkawa's (1984) fecundity relationship for opakapaka was used to predict the reproductive output as a function of size, and the maturity schedule of Ralston (1981) was used to define the onset of egg production. Individuals were assumed to spawn but once a year. Because opakapaka fecundity is roughly linear with age, the simulation is robust to violation of this assumption, i.e., multiple spawning, as long as spawning frequency is unrelated to fish size/age. The two cohorts were modeled under different mortality schedules. The first was characterized by t_c = 1.4 yr, corresponding to current state law governing harvest of opakapaka, and the other was set at t_c = 3.5 yr, corresponding to the present situation in the NWHI. Fishing mortality rate was fixed at 0.50 yr^{-1} in both runs, as was natural mortality rate at 0.25 yr^{-1} (Ralston 1981).

The simulation results showed that under these conditions a cohort of 1,000 opakapaka is expected to produce a total of 185 million eggs over its entire lifespan when t_c = 1.4 yr. In contrast, a similar number of individuals should produce 485 million eggs when t_c = 3.5 yr. The ratio of total egg production in the latter to that of the former is 2.62. A 162% increase in egg production can therefore be expected, simply by raising the weight at entry of opakapaka from 0.45 kg to 1.36 kg. This coupled with a 25% increase in Y/R could have a profound affect on yields from the MHI opakapaka fishery.

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